Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 97 (2013) 392 – 396

Procedia
Social and Behavioral Sciences

The 9th International Conference on Cognitive Science

Theory on improving reading for readers with abnormal eye saccades through colored filters

Parameswari Shunmugam[a,c,]*, Vijayakumar Vengadasalam[b], Muthusamy KA[c]

[a]*Port Dickson Polytechnic, Malaysia,*
[b]*Faculty of Engineering,Multimedia University, Melaka 75450, Malaysia*
[c]*Faculty of Medicine,University Malaya, Kuala Lumpur, Malaysia*

Abstract

In this paper, we propose a diffraction based model to explain how coloured filters are able to improve the reading abilities of readers with abnormal eye saccades. We have explained how light of short wavelengths such as blue forms a broader diffraction image compared to light of long wavelength such as red. It is known that blue filters appear to improve reading ability of dyslexics who often present with abnormal eye saccades. Since blue coloured light gives rise to a diffracted image with is broader, it activates both the centrally located parvocellular ganglions as well as the peripherally located magnocellular ganglions. Thus, both pathways formed by these ganglions are activated even if the saccades are abnormal. In the case of red light, since the diffracted image is narrower, the retinal activation region is also narrow matching the narrow retinal region rich in parvocellular ganglions. Images formed in eyes with abnormal saccades will result multiple crossings of a narrow pencil of the diffracted red light beam across the centrally located parvocellular ganglions resulting in a dramatic rise and fall in neural signal in the parvocellular pathway. This causes image instability resulting in unsteady, unclear and distorted images as seen by some poor readers.

Keywords: Dyslexia, reading disorder, abnormal eye saccades, improving reading, colored filters for better reading

1. Introduction

Good ability to read is the key criteria for a reader to become competent in the subject matter that he/ she is reading which would eventually help them to be successful in their learning process. Whereas, failure to read would lead the reader to be slow in his/ her studies and eventually drop out from the educational system. Inability to read would impede the learning process and lead to various psychosociological problems for the reader and his/her family. Most of the time, these type of poor readers would go unnoticed and suffer silently. Without immediate intervention and professional help, their reading problem would become permanent which would cause their talents to be wasted. The actual cause of poor reading could be many but the objective of this research is to focus on poor readers who are found to have abnormal eye saccades. Poor readers have often been found to have abnormal eye saccades which is a strong contributor to the Meares–Irlen Syndrome[1]. This syndrome is characterized by visual

* Corresponding author. Tel.: 016-3167614
E-mail address: parameswari@siswa.um.edu.my

doi:10.1016/j.sbspro.2013.10.250

stress (asthenopia) and those affected by this syndrome show Visual Perceptual Distortions (VPD) during reading activities. It has been found that the symptoms can be alleviated by individually prescribed colored filters [2]. The benefit from colored filters has been demonstrated through Wilkins Rate of Reading Test (WRRT)[3].

The syndrome is said to be particularly prevalent in people with reading difficulties, such as dyslexia, but can also occur in good readers [4]. Controlled research has shown that the benefit from colored filters cannot be solely attributed to the placebo effect [5] and is associated with an improvement in the rate of reading especially in reading accuracy and comprehension [6]. The aetiology of Meares–Irlen Syndrome is still not fully understood [7], but research suggests that the effect of color is not solely attributable to a contrast reduction with the filters [8], and is specific to a certain color for each individual [9] which is unlikely to be explained by refractive or ocular motor factors [10]. It has been suggested that the benefit from colored filters might be explained by the finding of a deficit of the magnocellular visual system in many people with dyslexia [11]. However, there are some inconsistencies in the magno-deficit hypothesis [12] and it is difficult to see how this hypothesis could account for the idiosyncratic and specific choice of color that is required in Meares–Irlen syndrome [13]. Furthermore, Meares –Irlen syndrome is not synonymous with dyslexia and studies that have directly assessed magno-function in Meares–Irlen syndrome have not found it to be abnormal [14]. Yet, dyslexia, has a high comorbidity with Meares–Irlen Syndrome [15]

2. Diffraction in the human eye

In the human eye, when the eye focuses on a point source of light, an image of the point source is brought to focus at the fovea of the retina as shown in Fig. 1. It can be shown that light of a given wavelength and intensity from a point source passing through the pupil will undergo diffraction which will result in intensity modifications of the light when it reaches the fovea. This intensity modification is dependent on various diffraction parameters such as the wavelength of light, radius of the pupil and position of the source. A light source which lies between the near-point and the far-point of the eye, emits monochromatic spherical light waves. These waves first undergo refraction at the cornea giving rise to a converging spherical wave at the plane of the pupil of the eye. The waves are then diffracted at the pupil and the resulting image serves as an object for the lens of the eye and with suitable scaling it is brought to focus on the retina to form the final image. The final image of a point source on the retina can be described as an Airy disk[16]. The characteristics of the Airy disk can be qualitatively understood using the concept of Fresnel zones which are zones of alternating phases at the exit-pupil plane[17]. The usual treatment for obtaining diffracted images consider sources as emitting diverging spherical waves. However in the case of the eye, diffraction methods for converging spherical waves through a circular aperture are needed to obtain a detailed diffracted image at the retina[18,19].

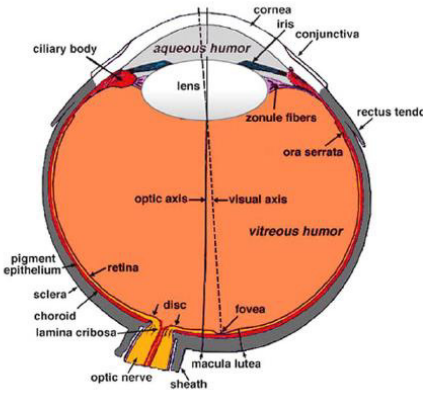

Fig. 1. Saggital view of the human eye

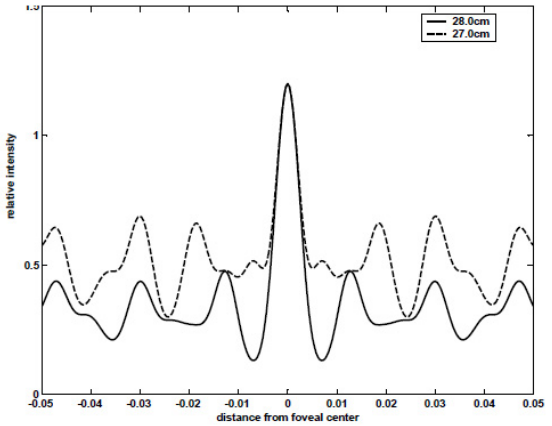

Fig. 2. Enlarged intensity plot of diffracted light at the retina of the human eye across the fovea for a 555nm (green) point light source at 27 cm and 28 cm

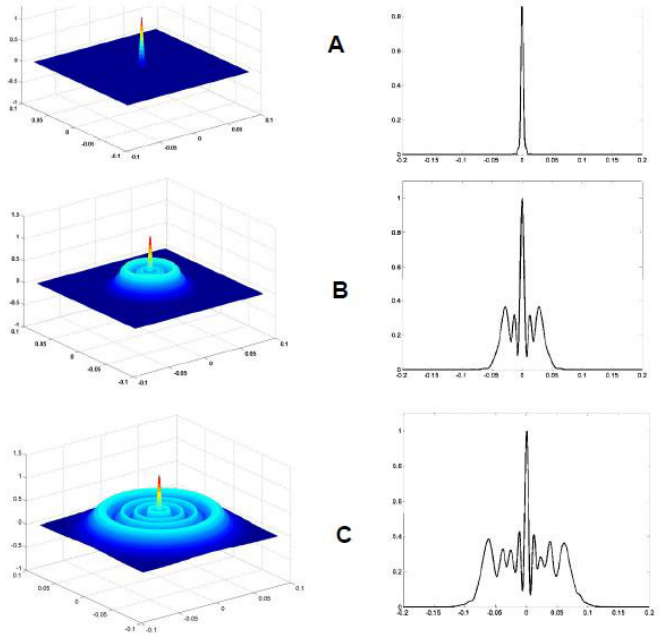

Fig. 3. 2-D and 3-D Intensity spectra of diffracted light at the retina of the human eye for source at (A) 500 cm, (B) 50 cm and (C) 28 cm (normalized intensity vs distance in mm from foveal center)

3. Simulated diffracted images and neural firing mechanism

The simulated diffracted images for point sources are shown in Fig 2. The entire diffracted image shown in Fig. 2, is contained within a bright spot on the retina with a diameter of approximately 0.2 mm. The width of the fovea is about 2 mm. This shows that the entire image lies within the fovea with the central portion of the image within the foveola. We can thus conclude that the spectral information from the entire image is conveyed to the brain directly

by the parvocellular pathway via the dedicated connection of a cone to at least one ganglion cell via midget bipolar cells and subsequently to the lateral geniculate nucleus (LGN) for further neural processing.

Note that the integrity of the entire image which is conveyed to the brain, depends on the simultaneous firing of the ganglion cells. There is experimental evidence for such simultaneous firing since a high correlation between ganglion cell output signals has been observed [20,21,22]. The amacrine cells appear to provide the mechanism for this correlation through coincidence detection [23,24].

The diffracted image of the point source is formed on the retina and it is sliced up and sent through different cone cells to the ganglion cells via the midget bipolar cells. The neural signals reaching the ganglion cells which are in disparate parts must be sent to the brain as a cohesive synchronous group since the neurons as a whole encode the entire diffracted image. The amacrine cells play a vital role in this process by acting as a coincidence detector and trigger [25,26]. Note that the discharges of correlated neurons peak within an interval of about 200 ms indicating that eye saccades with an average of about four saccadic eye movements per second, will not destroy this coincidence detection [27]

4. Use of colored filters

The use of blue colored filters now changes the entire scenario. Part of the diffracted image now spills outside the foveal region . The foveal region is rich in parvocellular ganglions whereas the region outside the fovea has a predominance of magnocellular ganglions. When there is an abnormal saccade, the image tends to drift from the central portion of the fovea which has a predominance of parvocellular ganglions towards the foveal periphery which is dominated by the magnocellular ganglion cells. However the neural signals in the two pathways is not lost though it may begin to fluctuate slightly. However, when a red filter is used, the diffracted image narrows and during abnormal saccades, the image now moves completely outside the fovea into magnocellular region and back to parvocellular region. The resulting perceived effect is the a the constant and clear image for blue filters and a distorted and unsteady image for a red filters.

5. Conclusion and future work

The proposed model suggests that the improvement in reading ability by the use of blue filters and the worsening effect by the use of red filters may be explained by considering the effect of diffraction in the eye. This theory also allows us to examine the effect of neural signal changes in quantitative detail by altering other parameters that affect diffraction. These may include background lighting which will alter pupil diameters and reading distance. These parameters will affect the size of the diffracted image and also similarly affect the neural signal process in the parvocellular as well as the magnocellular pathways. This suggests that an optimal combination of coloured filters with background lighting and reading distance would be needed to obtain the desired results for reading. Future work includes direct verification of the proposed model by using eye tracking devices, EEG and other imaging techniques to determine the real time fluctuation of neural signals in both the parvocellular and magnocellular pathways when various colored filters are used, during different background lighting conditions and various reading distances during reading .

References

[1] Biscaldi, M, Fischer, B, and Aiple, F.(1994) Saccadic eye movements of dyslexic and normal reading children. Perception. 1994;23(1):45-64

[2] Evans, B.J.W. (1997). Coloured filters and reading difficulties.: A continuing controversy. *Optometry and Vision Science,* 74, 239 – 240.

[3] Wilkins, A.J., Evans, B.J.W., Brown, J.A., Busby, A.E., Wingfield, A.E., Jeanes, R.J., & Bald, J. (1994). Double-masked placebo-controlled trial of precision spectral filters in children who use coloured overlays. *Opthalmic & Physiological Optics,* 14, 365 – 370.

[4] Irlen, 1991 Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. *Introduction to the electronic age*, New York: E-Publishing Inc; 1999, p. 281–304

[5] Robinson, G.L., & Foreman, P.J. (1999a). Scotopic sensitivity/Irlen Syndrome and the use of coloured filters: A long-term placebo-controlled study of reading strategies using analysis of miscue. *Perceptual and Motor Skills,* 88, 35 – 52.

[6] Robinson, G.L., & Foreman, P.J. (1999b). Scotopic sensitivity/Irlen Syndrome and the use of coloured filters: A long term placebo controlled and masked study of reading achievement and perception of ability. *Perceptual and Motor Skills,* 89, 83 – 113.

[7] Evans, B.J.W., & Joseph, F. (2002). The effect of coloured filters on the rate of reading in an adult student population. *Opthalmic & Physiological Optics,* 22, 535 – 545.

[8] Jeanes, R., Busby, A., Martin, J., Lewis, E., Stevenson, N., Pointon, D., & Wilkins, A. (1997). Prolonged use of coloured overlays for classroom reading. *British Journal of Psychology,* 88, 531 – 548.

[9] Wilkins, A.J., Jeanes, R.J., Pumfrey, P.D., & Laskier, M. (1996). Rate of reading test: Its reliability, and its validity in the assessment of the effects of coloured overlays. *Ophthalmic and Physiological Optics,* 16, 491 – 497.

[10] Scott, L., McWhinnie, H., Taylor, L., Stevenson, N., Irons, P., Lewis, E., Evans, M., Evans, B., & Wilkins, A. (2002). Coloured overlays in schools: Orthoptic and optometric findings. *Opthalmic & Physiological Optics,* 22, 156 – 165.

[11] Iovino, I., Fletcher, J.M., Breitmeyer, B.G., & Foorman, B.R. (1998). Colored overlays for visual perceptual deficits in children with reading disability and attention deficit/hyperactivity disorder: Are they differentially effective? *Journal of Clinical and Experimental Neuropsychology,* 20, 791 – 806.

[12] Greatrex and Drasdo (1995). The magnocellular deficit hypothesis in dyslexia: a review of reported evidence. Ophthalmic Physiol Opt. 1995 Sep;15(5):501-6.

[13] Evans, B.J.W., Patel, R., Wilkins, A.J., Lightstone, A., Eperjesi, F., Speedwell, L., & Duffy, J. (1999). A review of the management of 323 consecutive patients seen in a specific learning difficulties clinic. *Opthalmic and Physiological Optics,* 19, 454 – 466.

[14] Simmers, A.J., Bex, P.J., Smith, F.K.H., & Wilkins, A.J. (2001a). Spatiotemporal function in tinted lens wearers. *Investigative Ophthalmology & Visual Science,* 42, 879 – 883.

[15] Irlen, H. (2005). (Rev). *Reading by the Colors: Overcoming Dyslexia and Other Reading Disabilities Through the Irlen Method.* New York: Penguin.

[16] Westheimer, G. (2006). Specifying and controlling the optical image on the human retina. Progress in retinal and eye research, 25(1):19–42.

[17] F.W. Sears, in Optics, (Addison-Wesley Publishing Co., 3rd Ed, 1975), pp. 244-254.

[18] L. Yajun and E. Wolf, J. Opt. Soc. Am. A, 1(8), 801-808 (1984)

[19] L. Yajun, J. Opt. Soc. Am. A, 2(10), 1677-1686 (1985).

[20] M. Meister, L. Lagnardo and D.A. Baylor, Science 270, 5239 (1995).

[21] I.H. Brivanlou, D.K. Warland and M. Meister, Neuron 20, 527-539 (1998).

[22] Y. Tsukamoto, R.G. Smith, and P. Sterling, Proc. Natl. Acd. Sci., U.S.A. 87, 1860-1864 (1990).

[23] M.L. Veruli and E. Hartveit, Neuron 33, 935-946 (2002).

[24] A.D. Garbo, M. Barbi and S. Chillemi, in Advances in brain, vision, and artificial intelligence, (Springer, 2007), pp. 408-417.

[25] M.L. Veruli and E. Hartveit, All(Rod) amacrine cells form of electrically coupled interneurons in the mamallian retina", Neuron 33, 935-946 (2002).

[26] A.D. Garbo, M. Barbi and S. Chillemi, in Coincidence detector properties of small networks of interneurons", Advances in brain, vision, and artificial intelligence, (Springer, 2007), pp. 408-417.

[27] P. Maldonado, C. Babul, W. Singer, E. Rodriquez, D. Berger and Sonja Grun, Synchronization of neuronal responses in primary visual cortex of monkeys viewing natural images J. Neurophysiol., 100, 1523-1532 (2008).